STUDIES ON THE GENESIS OF METALLIC MINERAL
DEPOSITS OF SHINJO AND YAMAGATA BASINS,
NORTHEASTERN JAPAN (II)

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ORIGIN OF ORE DEPOSITS

The metallic mineral deposits situated within the Shinjo Basin and the Yamagata Basin include those of gold, silver, copper, lead, zinc, iron sulphides and others. All in all, they amount to more than 300 individual ore deposits, distributed within the granitic Basement rocks and largely, within the earlier and later stages of the Miocene sequence.

These ore deposits are generally hydrothermal in origin, formed by the process of magmatic differentiation. They tend to be concentrated in areas of igneous activity. (McKinstry, 1955). They are remarkably controlled by geologic structures produced by uplift of the Basement, orogenesis accompanied by folding of sedimentary rocks, and volcanic activity. The crushed zones, faults and fissures produced by these processes, served as the passageways for mineralizing solutions and depositional sites of the ore minerals (Emmons, 1948; Lewis, 1955).

The structures present in the area are roughly classified into those produced by the uplift of the granitic Basement and those produced by folding of the sedimentary rocks. Included in the former, are the N-S to NNE-SSW trending axis of the Basement Rise, the major faults parallel to this axis, and the subordinate faults and fissures perpendicular to it. Included in the later are the N-S, NNW-SSE trending fold axes, the major faults parallel to these axes, the crushed zone perpendicular to them, and the NE-SW trending tension cracks and crushed zones, within which are abundant E-W trending minor fractures cutting the trend of the fold axes obliquely (Billings, 1962).

These major structures, subordinate structures, and the combination of such structures, served as access to the flow of mineralizing solutions. They also served as access of the intrusions

Table 3. Number of veins in

Strike	80	70	60	50	40	30	20	W→ 10
Shinjo basin	12	9	2	2	1	5	4	3
%	8.6	6.4	1.4	1.4	0.7	3.6	2.8	2.1
Yamagata basin	5	3	8	6	5	3	0	2
%	2.7	1.6	4.3	3.2	2.7	1.6	0	1.1
both basin total	17	12	10	8	6	8	4	5
%	5.2	3.7	3.1	2.5	1.9	2.5	1.2	1.5

of dikes and sheets of "Tertiary granite", dacite, rhyolite and dolerite. With in and around these intrusive bodies are many different kinds of ore deposits (Schneiderhöhn, 1949; Lewis, 1955). Thus, the Nissho, Nakanomata and Kamuro ore deposits of northern Shinjo Basin are all related to the "Tertiary granite", and the ore veins trend parallel to the trend of the dikes of this igneous rock, or perpendicular to them. The Akayama and Shingoro ore deposits of southern Yamagata Basin are related to dacite dikes, and the ore bodies are lenticular in form, with their longer axes trending ENE. The deposit of Daiyama mine in eastern Shinjo Basin and that of Gando mine in eastern Yamagata Basin, occur as veins associated with numerous dolerite dikes. The massive ore deposits of Hotei, Daikoku and Ebisu of Yoshino District, western Yamagata Basin, occur along weak zones elongated along the NNE-SSW direction and parallel to the trend of the axis of the Basement Rise (Cloos, 1939; Lewis, 1955).

The stockwork deposits occur in areas where the major structures and subordinate structures cross each other. This is true in the case of the stockwork deposits of Fukufune, Daio, and Nobezawa of Shinjo Basin, and the Koyama, Honjo, Shuyama and Shirataka of Yamagata Basin. In these ore deposits the most important ore filled fissures making up the stockworks are those trending E-W.

In the Fukufune mine, the most abundant veinlets are those trending E-W, and those trending N-S are only next in abundance. In the Daio mine, the most abundant veinlets are those trending E-W, and this is followed by those trending NW-SE. In the Koyama mine, those trending practically E-W (N70W) are also the most

each directions

N-S	$\rightarrow \frac{E}{10}$	20	30	40	50	60	70	80	E-W	Total
0	4	4	1	7	10	27	18	16	15	140
0	2.8	2.8	0.7	5.0	7.1	19.3	12.8	11.4	10.7	100
5	7	12	10	13	15	24	21	23	23	185
2.7	3.8	6.5	5.4	7.0	8.1	13.0	11.4	12.4	12.4	100
5	11	16	11	20	25	51	39	39	38	325
1.5	3.3	4.9	3.3	6.8	7.7	15.7	12.0	12.0	11.7	100

abundant, and those trending practically N-S (N20E) are next in abundance. In the Shuyama mine, the E-W veinlets are also the most abundant, but other veinlets trend in almost every direction. In the Shirataka mine the NE-SW veinlets are the most abundant, and the E-W and NNW-SSE are only next in abundance. The remarkable abundance of the E-W trending veinlets show that the direction of compression in this region was along the E-W direction, at the time of the formation of the fissures filled by the ore veinlets (Lindgren, 1933; Mckinstry, 1942).

The vein type deposits are actually, relatively larger fissures filled with ore. The veins occurring within the granitic rocks of the Basement are those of: Akadakihi of Raidakihi mine and Tengu-zawahi of Kamuro mine, eastern Shinjo Basin; the 7 ore veins of Chiyogasawa mine, eastern Yamagata Basin; and the veins of Dainan mine, southeastern Yamagata Basin. All of these veins trend N-S, and parallel to the trend of the Basement axis. Those of: Daiyama mine, and Tengumori mine of eastern Shinjo Basin; the Himezawa ore deposit of eastern Yamagata Basin; and the Asahi and Nishizawa vein of Azuma mine, southern Yamagata Basin, all trend E-W and perpendicular to the Basement axis.

The veins filling fissures related to the uplift of the Basement, but within the sedimentary rocks are those trending N-S and E-W. Those related to the folding of sedimentary rocks are those trending NE-SW and ENE. The former are deposited mainly within the lowermost formation of the Miocene, while the latter are formed within most of the Miocene formations. The NE-SW and ENE trending veins are the most abundant of the vein type deposits, and they are

Table 4. Showing the relative abundance of ore vein system

Locality	No. of veins	Most abundant	abundant	Moderate	Scarce
Northern & eastern Shinjo Basin	93	$\pm N64E$	$\pm N75E$	$\pm E-W$	N-S or $\pm N30W$
Ou Backbone Range	115	$\pm N66E$	$\pm N85E$	N20E	$\pm N20W$
Gassan-Hayama Mountainland	92	$\pm N62E$	$\pm N85E$	N30-50E	$\pm N20W$
Over-all Shinjo & Yamagata Basins	300	$\pm N64E$	N70-90E	N40-50W	$\pm N20W$

the most important ore deposits within the two basins. The N-S and NW-SE trending fissures, within the upper formations of the Miocene, are very rarely filled with ore, because extreme pressure produced by the E-W lateral compression retarded the passage of mineralizing solutions along these routes (Newhouse, 1931).

The 140 ore veins of Shinjo Basin and the 185 ore veins of Yamagata Basin, lumped all together, strike ENE-WSW, which is also the strike of most of the veins taken individually. This structural trend makes an angle of about 60 degrees with the N-S trend of the major structural line of the region.

Accordingly, in the Shinjo Basin, those veins striking from N60E to N80W comprise 62.8% of the total number of veins within the basin. Among these, the N60E trending veins, which comprise 19.3%, are the most abundant. In the Yamagata Basin, those veins striking from N50E to E-W comprise 57.3% of the total number of veins within it. Among these, the N60E striking veins, which comprise 13.0% are the most abundant. The N80E and the E-W striking veins each comprise 12.4% of the total number of veins in the basin.

The veins occurring most scarcely are those striking N-S and N40W, in the Shinjo Basin and those striking N20W and N-S to N10W, in the Yamagata Basin. Considering both basins, these trends amount to NNW-SSE. Thus, it appears that the direction of the most abundant veins and that of the scarcest veins are perpendicular to each other.

As shown by the result of stereographic projection of the dip and strike of veins of the vein type deposits (see Table 4), the

Fig. 3. Distributional map of the ore deposits surrounding the Shinjo Basin.

1. Kanekura	12. Tengumori	23. Semi	34. Hiyama	45. Onakazima	56. Aramine
2. Nissho	13. Shirakawa	24. Kaninomata	35. Kanemori	46. Higashiyama	57. Nekodake
3. Marukura	14. Ryujin	25. Naknomata	36. Tomimori	47. Tachiyazawa	58. Nukumata
4. Nishikawa	15. Kamuro	26. Kumanogaeshi	37. Akakura	48. Okura	59. Taniguchi
5. Nakanomata	16. Raidaki	27. Tatekura	38. Asahi	49. Akasuna	60. Gabasawa
6. Kuromori	17. Uzen	28. Suginoiri	39. Tomikura	50. Yokozawa	61. Fukufune
7. Sugisawa	18. Hachimori	29. Yamagata	40. Gobono	51. Matsukura	62. Daio
8. Yanagihara	19. Mokuzo	30. Mitsuzawa	41. Kanewa	52. Takanosu	63. Tomiyama
9. Kamuro	20. Yoshizawa	31. Ritchu	42. Abeshiro	53. Nittetsugassan	64. Oboroge
10. Sawayama	21. Koizumi	32. Suganosawa	43. Nobezawa	54. Nagamatsu	65. Tateoka
11. Diayama	22. Takinosawa	33. Nagatomi	44. Tsuruko	55. Sotonagmatsu	

Fig. 4. Distributional map of the ore deposits surrounding the Yamagata Basin.

1. Showagassan	13. Nanamagari	25. Omoshiroyama	37. Gando	50. Nishigo	62. Ebisu	74. Motoasahi
2. Dennoyake	14. Takahi	26. Tateyama	38. Furuyashiki	51. Kondojiro	63. Shinsei	75. Hebikura
3. Fudodaki	15. Kinjo	27. Takase	39. Dainan	52. Takagami	64. Shinemi	76. Torihara
4. Ogidaira	16. Taisei	28. Joto	40. Toho	53. Futazaka	65. Shuyama	77. Ryumondaki
5. Hondoji	17. Yashiki	29. Bobara	41. Fubira	54. Nakazawa	66. Hisaka	78. Hyakunen
6. Sachi	18. Sanei	30. Umenoki	42. Osaka	55. Mansaku	67. Yoshinosekko	79. Ogura
7. Murayama	19. Nishizawa	31. Niiyama	43. Azuma	56. Yamazaki	68. Hiyama	80. Koyama
8. Miharu	20. Mutsuai	32. Himesawa	44. Kaneyama	57. Niijiku	69. Kumano	81. Fumoto
9. Wakayama	21. Tendo	33. Takara	45. Daiichi	58. Minamizawa	70. Shirataka	82. Taruishi
10. Hirano	22. Chiyogasawa	34. Takaratani	46. Honjo	59. Daikoku	71. Kageyama	83. Otaki
11. Takahata	23. Horai	35. Zazanosawa	47. Akayama	60. Hotei	72. Osuji	84. Chitose
12. Mitate	24. Uzen	36. Aburazawa	48. Kukeji	61. Yoshino	73. Murayama	

Fig. 5. Diagrams showing vein directions.

a : Northern to eastern of Shinjo Basin b : Mt. Gassan-Hayama
 c : Mt. Funagata-Zao d : All veins in the studied area

most abundant of 93 veins in northern and eastern Shinjo Basin are those trending $\pm N64E$; of the 115 veins in the Ou Backbone Range, the most abundant are those trending $\pm N66E$; and of the 92 veins in the Gassan-Hayama Mountainland area within the boundary between the two Basins, the most abundant are those trending $\pm N62E$. Considering the 300 veins present within these three areas, the most abundant are those trending $\pm N64E$; and next in abundance

Fig. 6. Distributional map of the ore deposit regions. D.G. = Deposit groups

Shinjo Basin: 1. Arisawayama D.G.; 2. Toyasawayama D.G.; 3. Tengumori D.G.; 4. Hachimori D.G.; 5. Akakura D.G.; 6. Nobezawa D.G.; 7. Kokuzo D.G.; 8. Hijiori D.G.; 9. Koshikidake D.G.;

Yamagata Basin: 10. Jizomoriyama D.G.; 11. Nishiyama D.G.; 12. Fumoto D.G.; 13. Omoshiroyama D.G.; 14. Hozawa D.G.; 15. Akayama D.G.; 16. Yoshino D.G.; 17. Asahi D.G.;

Outside of these Basins: (1) Innai D.G.; (2) Hosokura D.G.; (3) Obari D.G.; (4) Nezugaseki D.G.; (5) Kawasaki D.G.; (6) Fukuoka D.G.; (7) Miomote D.G.; (8) Oizumi D.G.;

Fig. 7. General direction of distribution of ore deposits.

are those trending $N70 \pm 90E$. The NNW-SSE trending veins are notably very scarce in any part of the two basins.

The more than 300 ore deposits within the Shinjo Basin and the Yamagata Basin may be grouped into three, namely: 1) those occurring the area from northern Shinjo Basin to northeastern Shinjo Basin, 2) those occurring in the area from the vicinity of Gassan-Hayama Volcano to eastern Yamagata Basin, and 3) those occurring in southern Yamagata Basin. The general direction of distribution of the ore deposits within each of these groups, as calculated by the method of least squares with the multinomial formula, $y = a_1x + a_0$, are shown in the table 6. This was processed in the NEAC-2230 type electronic computer.

Table 5. The distribution of ore districts according to ore region.

No.	Ore Region	Ore Districts
1	Northern to Eastern Shinjo Basin	1. Arisawayama, 2. Toyazawayama 3. Tengu-mori, 4. Hachimori, 5. Akakura, (1) Innai
2	Gassan-Hayama Volcano Vicinity to eastern Yamagata Basin	6. Nobezawa, 7. Kokuzoyama, 8. Hijiori 9. Koshikidake, 10. Jizomoriyama, 11. Nishiyama, 12. Fumoto, 13. Omoshiroyama, 14. Hozawa, (3) Yakuwayama, (5) Kawasaki, (6) Fukuoka
3	Southern Yamagata Basin	15. Akayama, 16. Yoshino, 17. Asahi, (7) Shichigashiku, (8) Mimote, (9) Otori

Table 6. The result of calculations.

Group No.	$y = a_1x + a_0$	$\theta = \tan^{-1}a_1$	Direction
1	$y = -0.6768x + 57.13$	$\tan^{-1}0.6768 = -34^\circ 05'$	N56°W
2	$y = -0.7022x + 34.56$	$\tan^{-1}0.7022 = -35^\circ 05'$	N55°W
3	$y = -0.6144x + 18.68$	$\tan^{-1}0.6144 = -32^\circ 41'$	N57°W

The result of these calculations shows that the general direction of distribution of the ore deposits within the 3 groups is N56W $\pm$ 1 degree. This direction makes a 60 degree angle with the major structural line trending $\pm$ N-S. Also, it makes an angle of 120 degrees with the previously mentioned most abundant direction of ore veins as gathered from stereographic projections, which is N64E $\pm$ 2 degrees. Thus, the major structural line ($\pm$ N-S) of both basins bisects the 120 degree angle made by the general direction of distribution of ore deposits (N56W $\pm$ 1) and the direction of the most abundant ore veins (N64E $\pm$ 2); and these three directions make an angle of 60 degree with one another. The ore veins are then arranged like a flight of wild geese, side by side with one another, with the general direction of distribution of ore deposits as the axis (Campbell, 1958).

The N56W line along which the 5 ore districts in the northeastern quadrangle of Shinjo Basin are distributed, passes through the southern part of Kaneyama Town, about 15 kilometers north of Shinjo City, and extends northwestward to the southern foot of Chokai Volcano and southeastward to Sakaida Hill, east of Akakura,

Basin. It runs parallel to and along the southern side of the mountain range separating Yamagata and Akita Prefectures which topographically changes to a plain. The 5 ore districts here, which includes the Akakura district are distributed along both sides of this line.

In the area from Gassan and Hayama Volcanoes to the eastern part of Yamagata Basin, another line trending N55W connects 9 ore districts and passes through Sagae City, about 15 kilometers north of Yamagata City, and extends northwestward to the southern foot of Gassan Volcano and southeastward to the Futaguchi Hill of Ou Mountain Range. These 9 ore districts, which includes the Nishiyama district are distributed on both sides of this line.

In between and flowing parallel to these two general directions is the Mogami River, which is considered a fault river. Thus, it is believed that these two alignments of ore deposits are related to tectonics.

In the southern part of Yamagata Basin, the N57W line connecting 3 ore districts passes through Iwabe Mountain, in between Kaminoyama City and Nanyo City in the southern and of Yamagata Basin, and extends northwestward to the southern foot of Oasahi Mountain and southeastward to the southern part of Kaneyama Hill. This general direction is parallel to the northern foot of the mountain range in between Yamagata and Yonezawa Basins. The northern part of this mountain range is bordered abruptly by the Yamagata Basin plain. The 3 ore districts here, which include the Yoshino district, are situated along both sides of this line.

In general, the ore deposits in both the Yamagata Basin and Shinjo Basin, are distributed in zones whose axes are the said three general directions or lines. These axes are believed to be the suitable tectonic zones for mineralization.

Localization of the ore deposits is mainly controlled by geological structures, but the roles of the kind of country rock and degree of alteration are also appreciable (Schneiderhöhn, 1952). In general fissures are more developed within shale and mudstone than within tuffaceous rocks, and especially when they are silicified the fissures are developed to the utmost (Hulin, 1948). This fact is well exhibited in the Koyama Mine. When the tuffaceous rocks are argillized, their roles become important in the formation of bonanzas in clay zones, as cap rock preventing the advance and dissemination of ore solutions (Lindgren, 1933). This is well exhibited in the

Miharu and Takahi Mines of northern Yamagata Basin.

The deposition of each of these massive type, network type, and vein type deposits are all structurally controlled by faults, fissures and crushed zones. Accordingly, the massive type ore deposits usually occupies the points where the aggregate of these structures is densest and this is surrounded by network type deposits, which, in turn is surrounded by vein type deposits (Hulin, 1929; Lewis, 1955). This is best shown by the Yoshino massive type deposit region of western Yamagata Basin. Here, the Ebisu, Daikoku, Hotei, Shinsei and Fukuju massive type ore deposits are surrounded by the network type deposits of Shuyama, Shirataka, Kumano, Kageyama, and Shinmei; and further these are surrounded by the vein type deposits of Shirogane, Oitama, Minamizawa and many others.

This transition of types of ore deposits also occurs in the vertical direction. For example, in the Bonten deposit of Koyama Mine, Nishiyama Ore District and in the Hisaka deposit of Yoshino Ore District, the massive type ore bodies gradually becomes network type downward and, further downward, it grades to vein type (Newhouse, 1942).

These metallic ore deposits of both basins are almost wholly deposited within the Basement granitic rocks and the formations earlier than the later stage of the Miocene. The faults and fissures which provided the routes of the ore solutions bringing about these mineralizations, were developed during the period from the Onnagawa stage to the Funakawa stage. During this period, uplift of the Basement was active and igneous activity brought about the "Tertiary granite", dacite, rhyolite and dolerite intrusives. Therefore, the stage of formation of the ore deposits corresponds to the Funakawa Stage. The Furuguchi formation of Shinjo Basin and the Ogureyama formation of Yamagata Basin are considered deposited during the later stage of the Miocene (Takeuchi, 1961). The volcanic activity and the uplift of the region, which started after the later stage of the Miocene and operative throughout the Pliocene, is still operative at present. Considering the distribution of ore deposits and the localization of hot-springs, the volcanic activity at this period appears to have a causal relationship with the igneous activity during the later stage of the Miocene which brought about the formation of the mineral deposits (Lindgren, 1933; Cloos, 1939; Lewis, 1955).

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新庄・山形両盆地に胚胎する金属鉱床の成因的研究

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摘 要

新庄・山形両盆地には、第三紀中新世の各地層がよく発達し、300 余りの金属鉱床が胚胎している。これらの鉱床を、新庄盆地北縁～東縁、新庄・山形両盆地境界、山形盆地南縁～東縁の三地域に分けて、夫々の鉱床地域の性状を地質および地質構造の関連において究明し、分析し、且つ整理した。

研究の結果、鉱床分布の総合的方位と、脈状鉱床の走向方位の最大密度方位とが、三つの鉱床地域ともに、両盆地の基幹構造線の方位に対して夫々相互に 60° で交わるという共通の規則性を帰納することを得た。

この事実から、両盆地に胚胎する金属鉱床は、成因的に共通の地質構造の規制を受けて生成したものと考えられる。